TECHNICAL NOTES

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No. 512

A COMPLETE TANK TEST OF THE HULL OF THE SIKORSKY S-40 FLYING BOAT - AMERICAN CLIPPER CLASS

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SUMMARY

The results of a complete test in the N.A.C.A. tank on a model of the hull of the Sikorsky S-40 flying boat ("American Clipper") are reported. The test data are given in tables and curves. From these data nondimensional coefficients are derived for use in take-off calculations and the take-off time and run for the S-40 are computed. The computed take-off time is found to agree substantially with the take-off time obtained by the Sikorsky Aviation Corporation in performance tests of the actual craft.

INTRODUCTION

The need for tank tests of a series of flying-boat hulls representative of the various types now in use is pointed out in reference 1. The results would not only allow the consideration of the relative merits of each type of hull, but would set a standard to which future developments might be referred. Such a series of tests has been undertaken by the N.A.C.A. and the subject test made during November and December 1933 is one of this series.

The Sikorsky S-40 flying boat known as the "American Clipper" having a hull that differs greatly from the more common American type seemed to be a logical subject for one of the series, and through the courtesy of the Sikorsky Aviation Corporation, the lines and offsets for this hull were obtained.

This hull has a transverse second step similar to conventional British hulls, but the general proportions of the hull differ considerably from British practice. The keel rises more rapidly at the bow, and the ratio of forebody length to afterbody length is much greater. As the tail surfaces on this craft are carried on outriggers, the usual long tail extending aft of the second step for this purpose is not necessary. In its stead, there is a short stubby tail.

APPARATUS AND METHODS

Method of Testing

The tests were made according to the complete method as described in reference 2. This method consists of measuring speed, load, trim angle, resistance, trimming moment, and rise in all combinations through the useful range. The independent variables chosen are speed, load, and trim angle.

The N.A.C.A. tank and its testing apparatus are described in reference 3. The modified towing gear used in these tests is described in reference 4. The pivot for the towing gear was placed at an arbitrary position marked "center of moments" on figure 1.

The Model

A $\frac{1}{7}$-scale model of the Sikorsky S-40 (N.A.C.A. model 26) was made of laminated wood, carefully sanded, painted, and rubbed. For simplicity the model was made with a flat plywood deck instead of the rounded deck used on the full-sized flying boat. The tolerance on model dimensions was ±0.02 inch. The principal lines of the model are shown in figure 1 and the offsets are given in table I.

Model Particulars

Over-all length	99.42 in.
Forebody length (F.P. to main step)	50.42 in.
Afterbody length (main step to second step)	31.79 in.
Maximum beam	17.86 in.
Step depth	.57 in.

Center of moments forward of step	4.25 in.
Center of moments above keel	14.56 in.
Angle of dead rise at main step	22°
Angle of keel forward of main step to base line	0°
Angle of keel aft of main step to base line	6.55°
Angle of keel aft of second step to base line	15.00°
Forebody - percentage of over-all length	50.7
- percentage of length to second step	61.3
Beam - percentage of over-all length	18.0
- percentage of length to second step	21.7
- percentage of forebody length	35.5
Step depth - percentage of beam	3.2

RESULTS

Test Data

The data obtained are given in table II. Positive moments are those which tend to raise the bow; the center about which these moments are taken is shown in figure 1. A stop is fitted in the moment measuring gear to prevent the moment spring from deflecting beyond its elastic limit. Moment values in the table followed by a plus sign indicate that the spring is against this stop and the moment is greater than the value read. The exact position of the stop is determined by the running conditions and the spring capacity therefore varies slightly. The values of resistance include the air drag of the model.

Resistance and trimming moment, with load as parameter, are plotted against speed in figures 2 to 7, each figure containing the values for one trim angle.

Righting moments and drafts at rest are given in figures 8 and 9. They are useful in longitudinal-stability calculations and in determining water lines of the hull for various static conditions.

Nondimensional Data

The method for the reduction of test data to a more directly usable form described in reference 2 is used with this model. Curves of resistance against trim angle with load as parameter are plotted for selected speeds, and these curves show for each load and speed a best trim angle which will give minimum resistance. Best trim angle and resistance at best trim angle are then cross-plotted against load and after reducing the values to nondimensional coefficients, they are plotted as resistance coefficient and best trim angle against speed coefficient. The moments are treated similarly. Plots of moment against trim angle as for resistance are made, and from these plots the moment for the best trim angle is determined. After cross-plotting moment at best trim angle against load and reducing to nondimensional coefficients as above, a plot of moment coefficient against speed coefficient is made. The nondimensional coefficients used are as follows:

Load coefficient, $C_\Delta = \dfrac{\Delta}{wb^3}$

Resistance coefficient, $C_R = \dfrac{R}{wb^3}$

Trimming-moment coefficient, $C_M = \dfrac{M}{wb^4}$

Speed coefficient, $C_V = \dfrac{V}{\sqrt{gb}}$

where Δ is the load on the water, lb.

R, water resistance, lb.

w, weight density of water, lb./cu.ft.

b, beam of hull, ft.

M, trimming moment, lb.-ft.

V, speed, ft./sec.

g, acceleration of gravity, ft./sec.^{2}

Note: w = 63.5 lb./cu.ft. for the water in the N.A.C.A. tank.

Curves of nondimensional data are given in figures 10 to 13. They are for the best trim angle only. Figure 10 gives the variation of best trim angle with C_V and C_Δ. Figures 11 and 12 both show variation of C_R with C_V and C_Δ. Figure 11 is more easily interpreted, whereas figure 12 is easier to use in take-off calculations. Variation of C_M is plotted in figure 13.

Precision of Test Data

The curves of test data as drawn are believed to be correct within the following limits:

Load	±0.3 lb.
Resistance	±0.1 lb.
Speed	±0.1 ft./sec.
Trim angle	±0.1°
Trimming moment	±1.0 lb.-ft.

It will be noted that there is considerable dispersion among the resistance points at high speeds. The explanation for this seems to lie in the cause of the comparatively high resistance at these speeds. The blister coming from the main step strikes the afterbody which, with its wide second step, presents a large area over which the water must travel. At high speeds this condition must produce considerable frictional resistance and, since it cannot be hoped that the blister will always follow exactly the same course even for apparently identical conditions, the resistance will necessarily vary accordingly.

Spray Photographs

Representative photographs of the spray are shown in figure 14. The photograph taken at $V = 52.5$ f.p.s. illustrates the condition previously referred to where the frictional resistance is high.

DISCUSSION OF RESULTS

The nondimensional data may be used to calculate take-off performance by the method in reference 2. The data given by Sottorf in reference 5 indicates that the scale effect should be small on a model of this size.

In figure 15, the load-resistance ratio is plotted against C_Δ for several values of C_V as an aid in comparing this model with others tested by the complete method.

In the selection of a hull for a particular design, take-off calculations should be made using each of the hulls under consideration. Such factors as the size of hull, angle of wing setting, etc., can then be taken into consideration.

CALCULATION OF TAKE-OFF TIME AND RUN

A comparison of computed take-off time with the take-off time obtained in performance tests of a full-sized flying boat should be of interest. For this purpose the take-off time for the S-40 flying boat will be computed using the following data supplied by the Sikorsky Aviation Corporation.

Data

Gross weight of Sikorsky S-40 . . . . 34,000 lb.

Wing:

Airfoil section	GS-1
Area	1,740 sq.ft.
Span	114 ft.
Angle of wing setting	2.5°

Power plant, 4 engines each developing at 2,000 r.p.m.	600 b.hp.
Propellers:	
Type	Hamilton Standard
Diameter	10 ft. 6 in.
Blade angle at 42-inch station	15.4°
Get-away speed	75 m.p.h. (110 f.p.s.)
Average take-off time with no wind	40 seconds

Propeller Thrust

Reference 6 gives curves for use in the determination of propeller thrust. The nominal blade angle at 0.75R is obtained by applying a correction (taken from fig. 7, reference 7) to the blade angle at the 42-inch station. The nominal blade angle at 0.75R is found to be 13.9°.

Extrapolation of data on blade deflections given in reference 8 indicates that for a 600-horsepower engine the effective blade angle is about 2° more than the nominal blade angle. The effective blade angle at 0.75R is therefore 15.9°. As a check on the accuracy of this extrapolation the blade angle required to hold the engine speed to 2,000 r.p.m. at maximum air speed may be obtained from figure 14 of reference 8. The maximum air speed of the S-40 is given in reference 9 as 137.4 m.p.h. Then $\frac{V}{nD} = 0.575$, $C_s = 1.164$. From figure 14 of reference 8 the blade angle at 0.75R required to hold engine to 2,000 r.p.m. is 16° and $\eta = 0.775$. This blade angle chocks closely with the effective blade angle 15.9°.

The thrust is determined from figure 12 of reference 6 and the total thrust (for four engines) is plotted in figure 16.

Lift and Drag Curves

A section of the GS-1 airfoil was included in the data supplied by the Sikorsky Aviation Corporation but no data regarding its characteristics were furnished. It was found by inspection that the GS-1 airfoil corresponded closely to the N.A.C.A. 4515 airfoil (reference 10) and it was assumed that the properties of this airfoil were a sufficiently close approximation for use in these calculations.

The reference line for the GS-1 airfoil is tangent to the bottom camber while the reference line for the N.A.C.A. 4515 airfoil is laid out from leading edge to trailing edge. The difference between these reference lines is about 2.8° so that the equivalent angle of wing setting for the N.A.C.A. 4515 airfoil is $2.5^\circ + 2.8^\circ = 5.3^\circ$.

At a maximum air speed of 201.5 f.p.s. (137.4 m.p.h.), thrust hp. = total b.hp. $\times \eta = 4 \times 600 \times 0.775 = 1860$ hp. and drag = thrust = $\dfrac{\text{thrust hp.} \times 550}{V_{max}} = \dfrac{1860 \times 550}{201.5} = 5080$ lb.

$$\text{From this,} \quad C_D = \frac{D}{\frac{\rho}{2} S V^2} = \frac{5080}{0.001189 \times 1740 \times (201.5)^2} =$$

$$\frac{5080}{84000} = 0.060 \quad \text{and} \quad C_L = \frac{L}{84000} = \frac{34000}{84000} = 0.405.$$

$$\text{Now} \quad C_D\ (\text{wing}) = C_{D_o} + C_{D_i} = C_{D_o} + \frac{{C_L}^2}{\pi AR}.$$

$$\text{Aspect ratio} = \frac{(114)^2}{1740} = 7.47.$$

From figure 46 of reference 10, for $C_L = 0.405$, $C_{D_o} =$ 0.11.

$$C_D\ (\text{wing}) = 0.011 + \frac{(0.405)^2}{\pi\ 7.47} = 0.018$$

C_{D_P} (including hull) = $C_D - C_D$ (wing) = $0.060 - 0.018 =$ 0.042.

But in the tank tests of the model the air drag of the hull is included in the resistance, so it must be deducted from this C_{D_P}. The cross-sectional area of the model converted to full size is 70 square feet. Assuming C_D (model hull) = 0.19*,

$$C_D \text{ (model hull) based on wing area} = \frac{0.19 \times 70}{1740} = 0.008$$

$$C_{D_P} \text{ (excluding model hull)} = 0.042 - 0.008 = 0.034$$

The ground effect on the wing is equivalent to a change in aspect ratio. It can be shown that,

$$\text{Effective aspect ratio} = \frac{\text{nominal aspect ratio}}{1 - \sigma}$$

where σ is an interference coefficient from reference 11.

To determine σ the water clearance Z is found to be about 17 feet.

$$\frac{2Z}{b} = \frac{2 \times 17}{114} = 0.298$$

and also $\mu = b_1/b_2 = 1$ for a monoplane. Then from figure 76 of reference 11, $\sigma = 0.39$.

$$\text{Effective aspect ratio} = \frac{7.47}{1 - 0.39} = 12.2.$$

In the following table values of α_0 and C_{D_0} taken from figure 46 of reference 10 are used in computing values of C_D and C_L for the complete flying boat (excluding the hull) for an aspect ratio of 12.2. The values of C_D and C_L thus obtained are plotted against α in figure 17.

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*This value is taken from preliminary data of wind-tunnel tests now being made with models of this and other hulls.

C_L	α_o, deg.	α_i,* deg.	α (boat) $\alpha_i + \alpha_o$, deg.	C_{D_o}	C_{D_i} $C_L^2/\pi AR$	C_D $C_{D_o} + C_{D_i} + C_{D_P}$
0	-4.0	0	-4.0	0.012	0	0.046
.2	-2.0	.3	-1.7	.011	.001	.046
.4	0	.6	.6	.011	.004	.049
.6	2.0	.9	2.9	.012	.009	.055
.8	4.2	1.2	5.4	.014	.017	.065
1.0	6.5	1.5	8.0	.016	.026	.076
1.2	8.8	1.8	10.6	.020	.038	.092
1.4	11.3	2.1	13.4	.027	.051	.115
1.6	15.0	2.4	17.4	.055	.067	.156

$*\alpha_i = \frac{C_L}{\pi AR} \times \frac{180}{\pi}$.

Take-Off Time and Run

The time and length of run required for take-off are now computed as in reference 2, using the curves of thrust (fig. 16), C_L and C_D (fig. 17) previously computed. Total resistance $(R + D)$ is plotted with the thrust curve in figure 16. The values of $1/a$ and V/a $\left(a = \frac{g}{W}[T - (R + D)]\right)$ are plotted in figure 18. The area under the $1/a$ curve gives the take-off time and the area under the V/a curve gives the length of take-off run. Time and run are determined for "normal" take-off (i.e., holding the craft at best trim angle until it takes off) and for a pull-off at 110 f.p.s. (the get-away speed given by the manufacturers).

The results are as follows:

Get-away speed f.p.s.	Take-off time sec.	Length of run ft.
123.8 (normal)	46	3,500
110 (pull-off)	38	2,600

The computed take-off time for 110 f.p.s. get-away speed agrees remarkably well with the average take-off time of the actual craft given by the Sikorsky Aviation Corporation as 40 seconds. Although the manufacturers supplied no data regarding the length of take-off run, they stated that the computed results agreed very well with the results obtained from flight tests.

CONCLUDING REMARKS

Although the agreement of the results obtained is encouraging, the need for a full-sized check on model results has not been filled. Compensating errors in the assumptions made could easily account for a close agreement even when individual items are seriously in error.

It is believed that there exists a real need for tests, on a full-sized seaplane, in which sufficient data to afford a more accurate comparison would be obtained. Accurate data on the aerodynamic characteristics of the flying boat and a record of the trim angles obtained during the tests are essential to a strict comparison between the model tests and full-sized tests.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 30, 1934.

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TABLE I. OFFSETS IN INCHES FOR MODEL 26

Station	Distance from F.P.	Distance from base line: Keel	Distance from base line: Chine	Distance from base line: Tangency bottom flare	Distance from base line: Radius center	Half-breadths: Chine	Half-breadths: Tangency bottom flare	Half-breadths: Radius center	Half-breadths: Deck	Radius bottom flare
F.P.	0	0							0.18	
1/2	1.33	4.25	4.25	4.25		0.18	0.18		1.08	
1	3.12	7.63	4.83	5.25	5.65	1.46	1.16	2.13	2.21	1.06
2	4.83	9.13	5.34	6.08	7.37	2.60	1.96	4.18	3.18	2.57
3	6.55	10.10	5.82	6.79	9.09	3.62	2.61	5.76	4.04	3.90
4	8.62	10.89	6.35	7.49	11.05	4.69	3.23	7.21	4.98	5.33
5	10.69	11.41	6.82	8.07	12.71	5.59	3.71	8.11	5.77	6.40
7	14.83	12.05	7.64	8.94	15.59	6.95	4.37	9.32	7.04	8.28
9	18.97	12.44	8.29	9.60	17.64	7.91	4.69	9.79	7.92	9.54
11	22.88	12.70	8.77	10.08	19.86	8.45	4.79	10.36	8.45	11.26
13	26.76	12.87	9.14	10.45	21.74	8.74	4.79	10.75	8.74	12.76
15	30.42	12.95	9.39	10.68	23.17	8.88	4.79	10.96	8.88	13.93
17	33.85	12.99	9.58	10.81	24.03	8.93	4.79	11.01	8.93	14.58
19	37.28	13.00	9.70	10.90	24.79	8.93	4.79	11.09	8.93	15.25
21	40.71	13.00	9.79	10.98	25.46	8.93	4.79	11.15	8.93	15.82
23	44.03	13.00	9.88	11.04	26.08	8.93	4.79	11.16	8.93	16.34
25	47.22	13.00	9.98	11.09	26.27	8.93	4.79	11.07	8.93	16.43
27,F	50.42	13.00	10.07	11.14	26.39	8.93	4.79	10.93	8.93	16.44
27,A	50.42	12.43	8.90			8.93			8.93	
29	54.78	11.93	8.40			8.92			8.92	
31	58.89	11.45	7.96			8.85			8.85	
33	63.00	10.97	7.56			8.63			8.63	
35	67.21	10.50	7.22			8.29			8.29	
37	71.49	10.00	6.94			7.79			7.79	
39	75.78	9.51	6.72			7.10			7.10	
40	77.92	9.30	6.67			6.69			6.69	
41	80.06	9.15	6.71			6.23			6.23	
42,F	82.21	9.11	6.86			5.75			5.75	
42,A	82.21	8.75	6.27							
44	87.06	7.45	5.52			4.50			4.50	
46	91.92	6.14	4.87			3.03			2.98	
48	96.78	4.84	4.34			1.29			.98	
Sternpost									.29	
A.P.	99.42	4.12	4.08			.29				

TABLE II

Test Data for N.A.C.A. Model No. 26 Flying-Boat Hull

Kinematic viscosity = 0.000014 ft.^{2}/sec.
Water density = 63.5 lb./cu.ft. Water temperature = 52° F.

Note: Positive moments tend to raise the bow

Load, lb.	Speed, f.p.s.	Resistance, lb.	Trimming moment, lb.-ft.	Draft at step, in.
Trim angle, τ = 2°				
5	29.5	5.0	2	1.1
	35.3	5.7	1	1.1
	39.2	6.8	1	1.1
	44.8	7.4	1	.9
	48.8	8.4	1	.9
	54.0	10.0	1	.8
10	30.0	7.3	5	1.5
	35.3	8.8	4	1.3
	39.5	9.6	3	1.2
	44.3	10.6	3	1.1
	48.8	11.0	3	1.1
	49.5	11.5	3	1.1
	53.6	12.8	3	1.1
60	6.0	3.1	9	4.7
	7.8	6.6	36	4.9
80	5.9	3.7	7	5.3
	7.9	8.7	42	5.6
100	5.9	4.2	3	5.8
	7.7	10.3	45	6.2
120	5.9	4.6	-3	6.3
	7.7	12.1	46	6.8
Trim angle, τ = 3°				
5	20.7	2.5	3	1.4
	23.0	2.9	2	1.2
	23.2	3.0	4	1.2
	26.3	3.4	2	1.1
	31.4	4.1	2	1.0
	36.7	4.6	2	.8
	37.4	4.9	1	.9
	42.1	6.4	1	.9
	46.7	6.3	2	.8
	46.7	6.9	1	.9
	51.8	7.3	2	.7
	56.0	8.2	2	.6
10	21.1	3.7	6	1.8
	23.2	4.4	5	1.5
	26.2	4.7	4	1.3
	31.4	6.0	5	1.2
	36.8	7.3	4	1.1
	37.3	6.7	2	1.1
	41.7	8.2	3	1.2
	46.3	8.6	2	1.0
	46.7	9.0	2	1.0
	51.9	10.5	4	.9
	55.7	11.0	2	.8
20	17.1	4.3	11	2.4
	19.1	4.7	12	2.4
	20.8	5.4	11	2.3
	23.1	6.2	11	1.9
	26.0	6.8	11	1.9
	31.4	8.7	10	1.7
	36.9	10.1	8	1.5
Trim angle, τ = 3°				
20	42.2	11.7	6	1.3
	46.6	12.5	6	1.2
	52.5	14.3	6	.9
	56.0	15.5	6	1.1
40	12.3	6.9	30	3.7
	13.9	8.0	42	3.6
	16.7	8.3	46	3.4
	17.0	7.9	40	3.3
	18.7	7.8	36	3.2
	20.8	8.5	30	2.8
	23.2	8.5	24	2.5
	26.2	10.0	23	2.3
	31.5	11.5	19	1.8
	36.9	13.8	19	1.9
	41.9	16.3	20	1.8
	46.2	17.6	18	1.4
60	6.8	4.6	6	4.8
	9.5	7.7	29	4.8
	10.2	8.3	30	4.8
	12.4	10.1	37	4.6
	13.8	11.9	54	4.4
	16.7	14.0	63+	4.4
	18.7	13.2	59+	4.2
	20.7	13.4	59+	3.4
	22.6	12.7	59+	2.9
	26.2	12.7	42	2.6
	31.3	15.4	31	2.2
	36.9	17.4	30	2.2
	42.5	19.7	30	2.0
80	6.8	5.5	4	5.6
	9.5	10.4	36	5.7
	10.1	11.0	37	5.5
	12.2	13.1	42	5.2
	13.6	14.9	53	5.1
	16.6	21.2	66+	5.3
	26.0	17.1	62+	3.1
	31.5	17.2	45	2.3
	37.0	19.8	40	2.3
100	6.7	6.2	0	6.2
	9.5	12.9	43	6.2
	10.0	13.5	44	5.9
	11.6	17.5	43	5.9
	14.2	23.8	51	5.8
120	6.6	7.0	2	6.5
	9.5	15.7	49	6.8
	9.9	16.8	50	6.6
	11.7	20.1	48	6.4
Trim angle, τ = 5°				
5	20.8	2.1	1	0.8
	22.8	2.0	1	.8
	24.8	2.1	1	.9
	30.6	3.7	1	.9
	34.9	4.4	3	.7
	40.2	5.9	3	.7

TABLE II (Continued)

Test Data for N.A.C.A. Model No. 26 Flying-Boat Hull

Kinematic viscosity = 0.000014 ft.^{2}/sec.
Water density = 63.5 lb./cu.ft. Water temperature = 52° F.

Note: Positive moments tend to raise the bow

Trim angle, τ = 5°

Load, lb.	Speed, f.p.s.	Resistance, lb.	Trimming moment, lb.-ft.	Draft at step, in.
5	45.2	7.3	3	0.7
	50.5	9.0	3	.7
	55.5	9.7	3	.5
10	20.9	3.0	1	1.2
	23.0	3.1	2	1.1
	24.9	3.2	2	1.1
	30.6	4.5	2	1.0
	34.5	5.3	3	.9
	40.3	7.4	2	.8
	42.0	7.4	3	.8
	42.0	8.0	3	1.0
	45.0	9.0	2	.8
	50.6	10.3	3	.8
	55.2	11.0	3	.8
20	16.7	3.8	5	1.8
	18.7	4.2	5	1.9
	20.9	4.5	4	1.7
	23.2	4.9	5	1.5
	24.9	4.9	4	1.6
	30.8	6.3	3	1.2
	35.8	7.7	3	1.1
	41.1	9.8	1	1.0
	42.0	9.6	2	1.1
	45.0	11.0	1	1.0
	50.2	12.5	3	1.0
	55.2	14.8	1	.9
40	12.3	6.3	10	3.2
	14.3	6.9	26	3.1
	16.2	7.1	26	2.8
	16.5	6.9	22	2.5
	18.3	6.6	16	2.4
	20.8	7.2	11	2.1
	22.7	7.4	12	1.9
	24.5	7.6	11	2.0
	30.3	8.8	11	1.7
	35.1	10.4	9	1.5
	40.1	12.5	7	1.4
	45.0	14.9	5	1.2
	45.2	14.5	5	1.3
	50.0	16.6	3	1.1
60	6.0	3.1	-35	4.4
	8.2	6.3	-7	4.6
	10.3	7.3	-4	4.3
	11.4	8.2	3	4.1
	12.4	8.9	7	3.9
	12.6	9.0	9	4.1
	14.0	10.9	42	4.0
	16.2	11.5	57	3.6
	16.5	11.3	57	3.5
	18.3	10.8	46	3.4
	21.0	10.5	30	2.5
	22.8	10.6	26	2.1
	24.2	10.5	20	2.4
	30.3	11.6	16	2.0
	35.4	13.1	15	1.8
	40.7	15.3	14	1.5
	45.0	17.3	11	1.5

Load, lb.	Speed, f.p.s.	Resistance, lb.	Trimming moment, lb.-ft.	Draft at step, in.
80	6.0	3.7	-45	5.0
	8.2	8.4	-6	5.3
	10.1	11.5	5	5.2
	11.2	11.1	5	4.9
	12.4	11.4	9	4.7
	12.7	11.7	12	4.5
	14.0	14.0	35	4.6
	16.0	16.9	64+	4.6
	16.7	17.1	63+	4.4
	18.3	16.2	63+	4.3
	20.8	14.9	60+	3.1
	22.8	14.2	50	2.8
	24.2	13.9	42	2.8
	30.4	14.9	23	2.2
	35.1	15.8	21	2.0
100	6.0	4.2	-45	5.6
	8.3	10.8	-6	5.8
	10.2	13.9	10	5.5
	11.2	15.2	12	5.4
	12.5	14.8	16	5.3
	12.8	14.9	18	5.2
	13.7	17.1	33	5.0
	16.2	23.0	69+	5.5
120	5.9	4.6	-47	6.1
	8.2	12.7	-7	6.4
	10.0	16.3	13	6.1
	12.4	19.8	20	5.9

Trim angle, τ = 7°

Load, lb.	Speed, f.p.s.	Resistance, lb.	Trimming moment, lb.-ft.	Draft at step, in.
5	21.2	2.7	1	0.9
	23.2	3.4	0	.9
	26.0	4.3	0	.8
	28.8	5.1	0	.7
	34.4	7.2	-1	.5
	40.0	9.2	-1	.6
	45.2	11.0	-2	.5
	49.5	11.9	-3	.3
	54.5	13.6	-3	.3
10	20.8	3.3	2	1.3
	23.2	3.9	1	1.1
	26.2	5.0	0	1.0
	28.8	6.0	-1	.9
	34.6	8.1	-2	.8
	39.8	10.5	-5	.7
	44.2	12.0	-4	.7
	49.8	13.9	-6	.5
	54.3	16.1	-6	.4
20	17.2	3.9	2	1.8
	19.0	4.0	3	1.8
	21.2	4.5	2	1.7
	23.1	5.2	2	1.4
	26.2	6.4	0	1.4
	29.0	7.5	0	1.2
	34.7	10.4	-3	1.2
	40.6	12.7	-8	.8
	44.8	14.4	-11	.8
	50.0	16.5	-12	.7
	54.2	19.2	-13	.6

TABLE II (Continued)

Test Data for N.A.C.A. Model No. 26 Flying-Boat Hull

Kinematic viscosity = 0.000014 ft.^{2}/sec.
Water density = 63.5 lb./cu.ft.   Water temperature = 52° F.

Note: Positive moments tend to raise the bow

Trim angle, $\tau = 7^\circ$				
Load, lb.	Speed, f.p.s.	Resistance, lb.	Trimming moment, lb.-ft.	Draft at step, in.
40	12.2	6.3	-8	3.0
	14.3	7.1	2	2.6
	15.7	7.0	6	2.5
	16.7	7.0	6	2.3
	18.5	7.1	6	2.3
	20.3	7.2	6	2.1
	22.3	7.3	6	1.9
	25.8	8.2	6	1.8
	28.7	9.5	5	1.6
	34.5	12.6	2	1.3
	40.0	15.5	-6	1.1
	44.8	18.0	-12	1.0
	50.0	20.5	-19	.9
60	5.8	3.1	-57+	4.2
	7.9	6.1	-36	4.4
	10.0	7.0	-28	4.1
	12.0	8.5	-19	3.8
	14.2	10.7	15	3.6
	15.5	10.8	25	3.4
	16.5	11.0	24	3.2
	18.8	10.8	22	2.8
	20.5	10.7	16	2.4
	22.1	10.8	12	2.3
	25.8	11.1	10	1.8
	28.5	11.7	8	1.9
	34.4	14.4	6	1.6
	40.0	17.6	1	1.2
	45.0	21.3	-6	1.1
80	5.8	3.7	-57+	4.9
	7.9	8.3	-43	5.0
	10.0	9.5	-28	4.8
	12.0	11.1	-20	4.5
	14.2	14.0	13	4.3
	15.5	15.3	47	4.2
	16.7	15.6	54	4.0
	18.8	15.2	47	3.4
	20.3	14.8	37	2.9
	22.0	14.6	28	2.6
	25.8	14.5	13	2.1
	28.6	15.0	12	2.0
	34.5	16.6	11	1.9
100	5.8	4.3	-57+	5.6
	7.9	9.8	-48	5.7
	10.0	12.3	-30	5.4
	12.0	14.2	-16	5.1
	14.0	17.2	8	4.8
	15.5	19.9	57	5.0
	16.5	20.9	65+	4.8
	18.5	20.4	66+	4.3
	20.5	19.4	64+	3.5
	22.2	18.6	49	3.0
	25.7	18.0	28	2.4
120	5.8	4.8	-59+	6.0
	7.8	11.8	-49	6.3
	9.8	15.2	-29	6.0
	12.0	17.4	-15	5.7
	14.0	20.5	12	5.4

Trim angle, $\tau = 9^\circ$				
Load, lb.	Speed, f.p.s.	Resistance, lb.	Trimming moment, lb.-ft.	Draft at step, in.
20	16.8	4.8	-16	1.5
	18.8	5.5	-11	1.7
	20.8	6.1	-4	1.4
	22.7	6.8	-5	1.3
	25.7	8.0	-12	1.0
40	11.5	6.8	-33	2.5
	13.6	7.2	-25	2.2
	15.6	7.5	-21	2.2
	18.0	8.0	-10	2.1
	20.0	8.3	-3	1.9
	22.4	9.2	0	1.7
	25.1	10.5	0	1.6
60	7.5	6.2	-43	4.1
	9.5	7.7	-42	3.7
	11.5	9.5	-38	3.3
	13.5	11.0	-19	3.1
	15.7	11.8	-7	2.6
	18.0	11.9	-3	2.4
	20.0	12.2	-2	2.2
	22.4	12.3	2	2.0
	25.0	13.0	3	1.9
80	7.5	8.1	-45	4.7
	9.5	10.1	-43	4.5
	11.6	12.4	-42	4.1
	13.6	14.4	-20	3.8
	15.7	15.7	9	3.4
	17.9	16.3	16	3.1
	20.0	16.2	9	2.5
	22.2	16.5	6	2.3
	25.1	16.4	5	1.9
100	7.5	10.2	-45	5.4
	9.4	12.6	-43	5.1
	11.7	15.3	-42	4.9
	13.6	17.7	-20	4.5
	15.8	20.3	27	4.3
	17.8	20.7	41	3.8
	20.0	20.7	9	3.2
	21.9	20.5	8	2.6
	25.1	20.1	9	2.1
120	7.5	12.0	-45	6.0
	9.4	15.5	-43	5.7
	11.6	19.1	-49	5.5

Trim angle, $\tau = 11^\circ$				
Load, lb.	Speed, f.p.s.	Resistance, lb.	Trimming moment, lb.-ft.	Draft at step, in.
100	16.6	21.6	-29	3.1
	18.6	22.0	-29	2.9
	20.5	22.1	-30	2.4
	22.4	22.8	-35	2.2
	25.6	22.9	-28	2.0

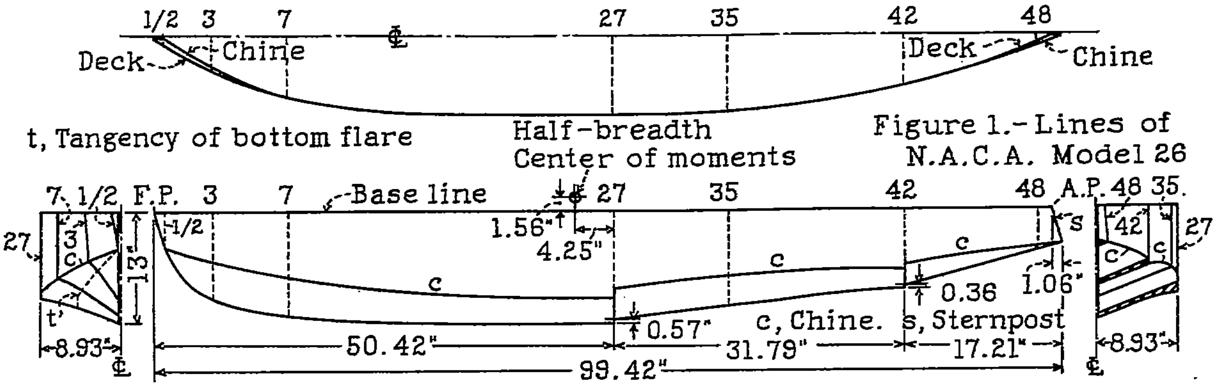

Figure 1.- Lines of N.A.C.A. Model 26

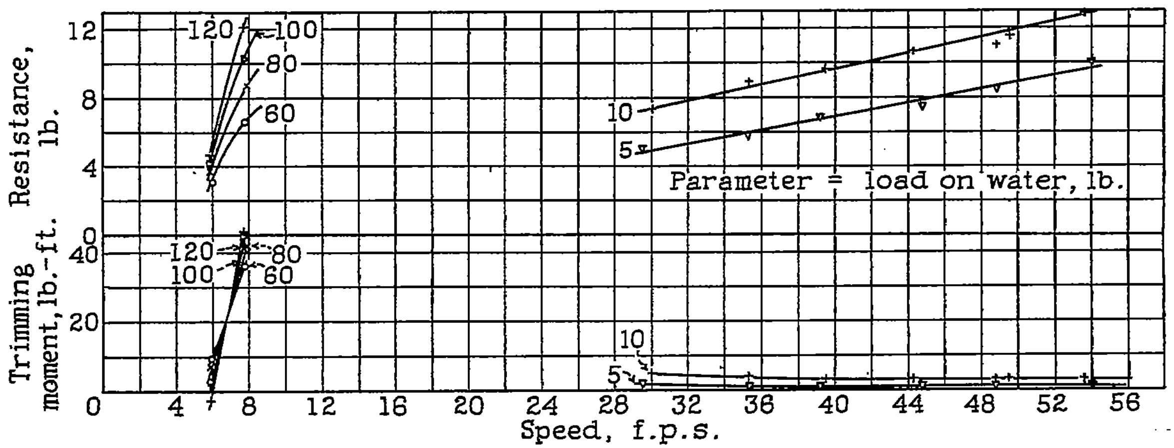

Figure 2. - Resistance and trimming moment, $\tau = 2°$. Model 26.

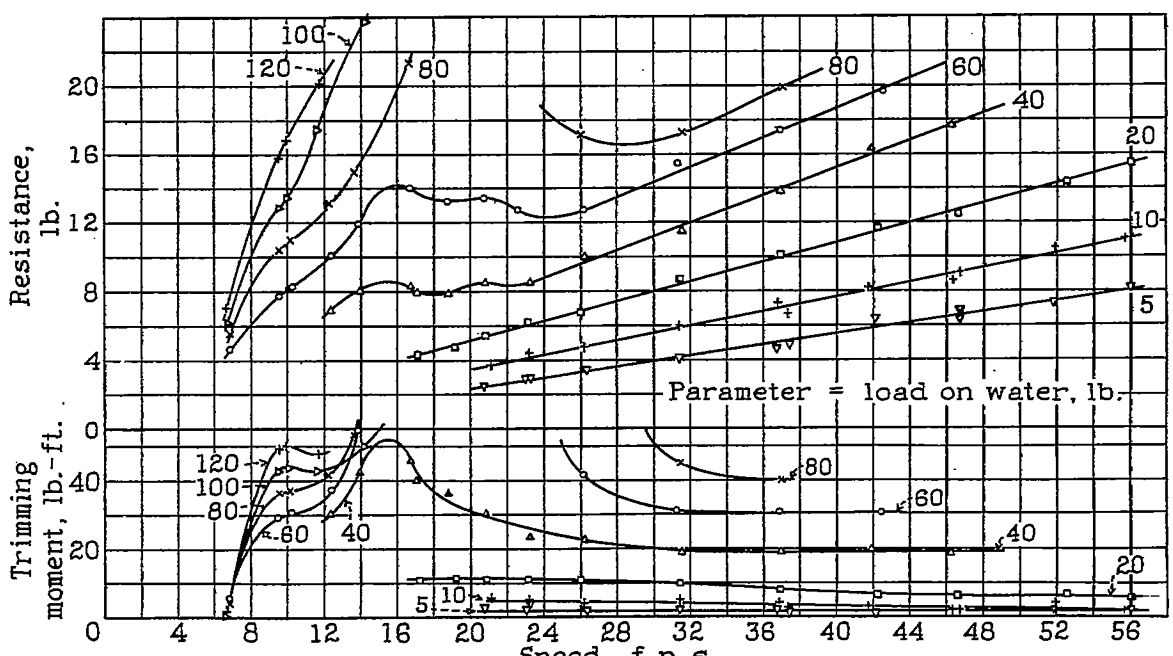

Figure 3. - Resistance and trimming moment, $\tau = 3°$. Model 26.

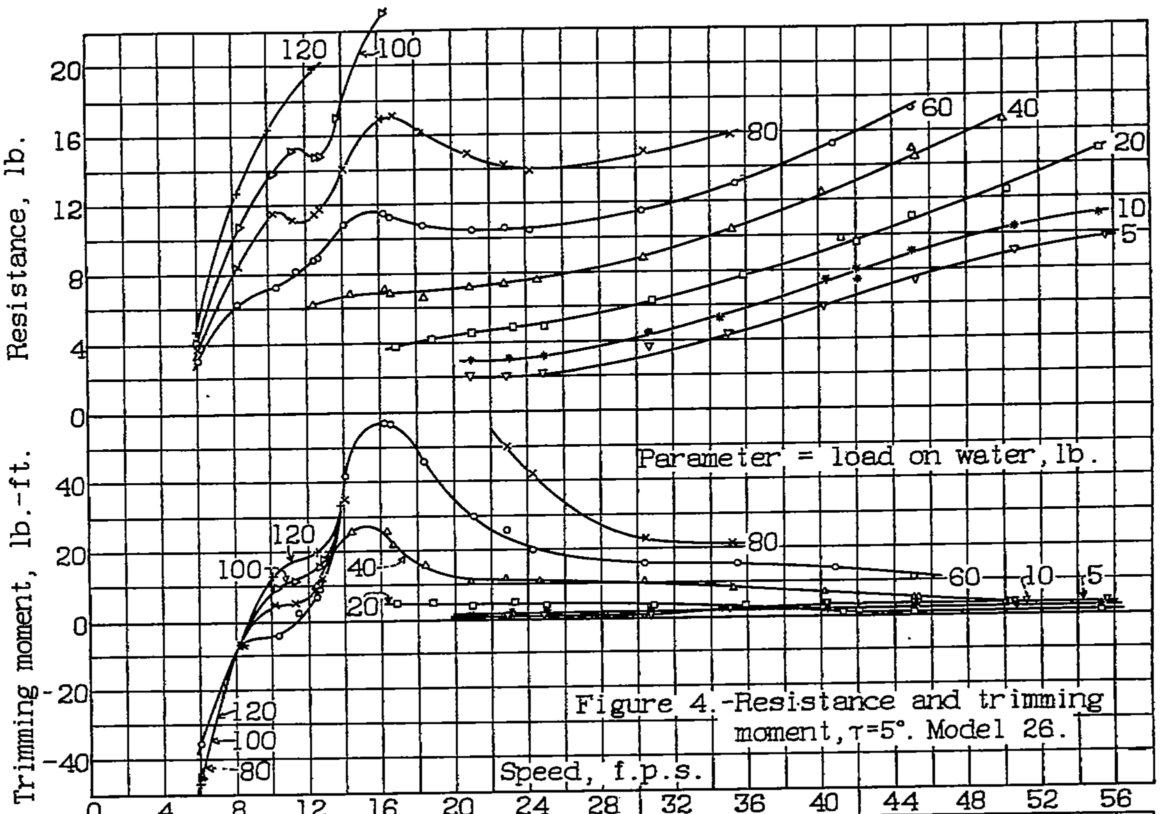

Figure 4.-Resistance and trimming moment, τ=5°. Model 26.

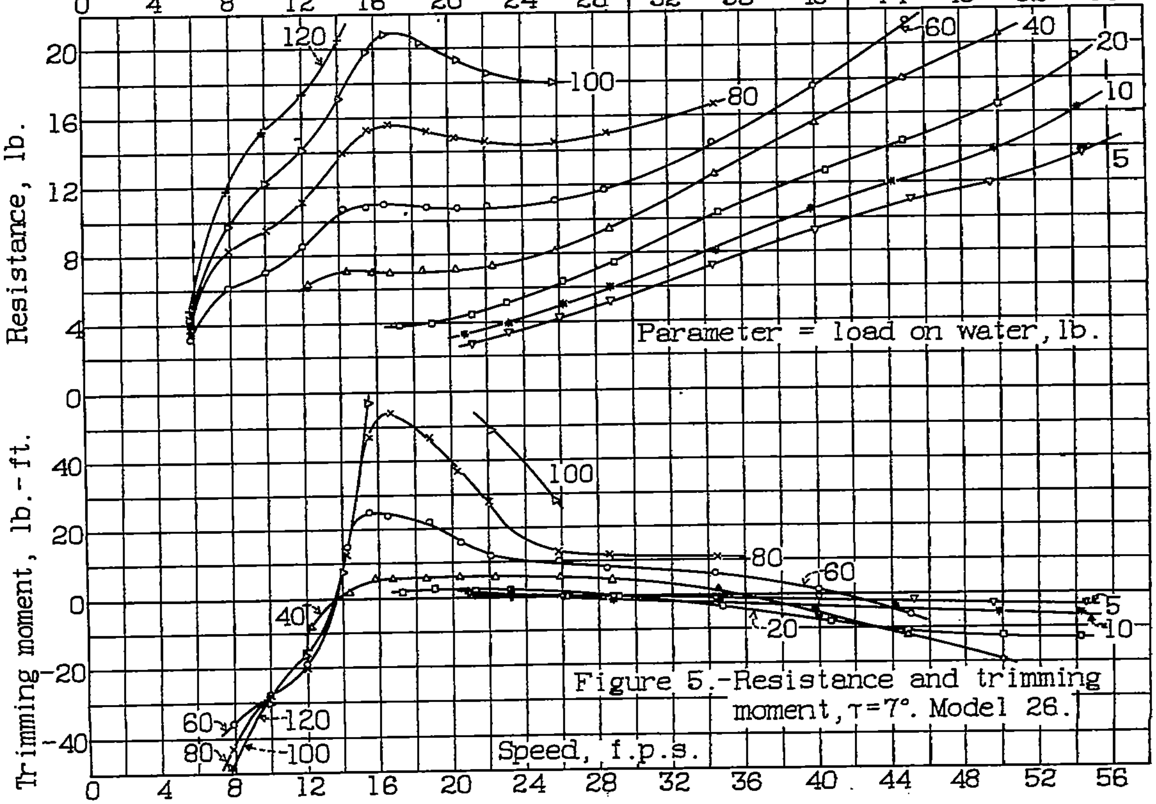

Figure 5.-Resistance and trimming moment, τ=7°. Model 26.

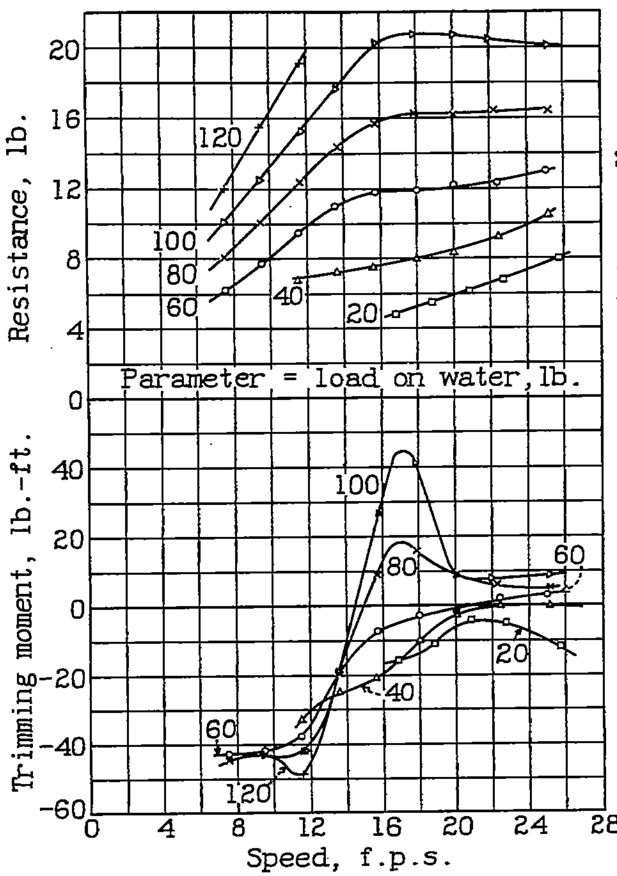

Figure 6.-Resistance and trimming moment, τ=9°. Model 26.

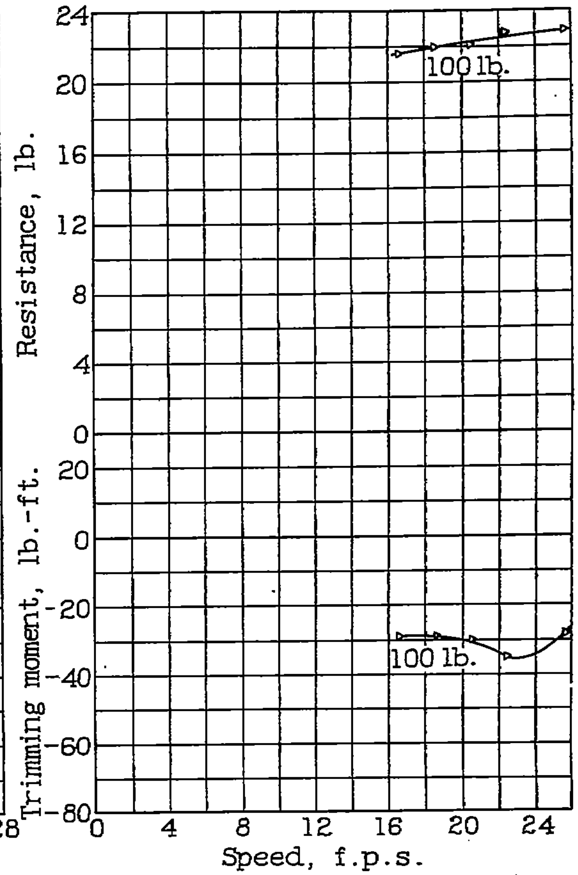

Figure 7.-Resistance and trimming moment, τ=11°. Model 26.

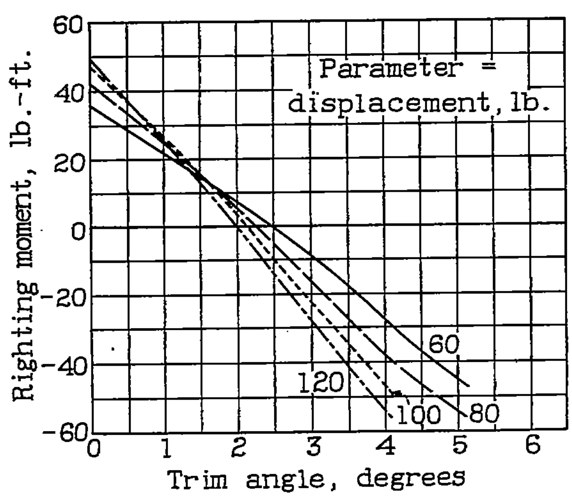

Figure 8.-Righting moments at rest. Model 26.

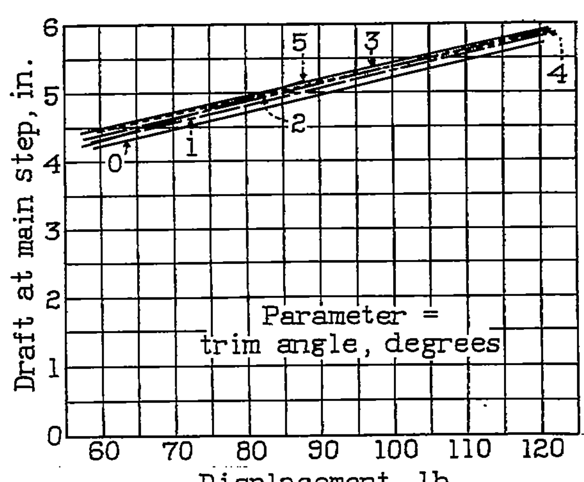

Figure 9.-Drafts at rest. Model 26.

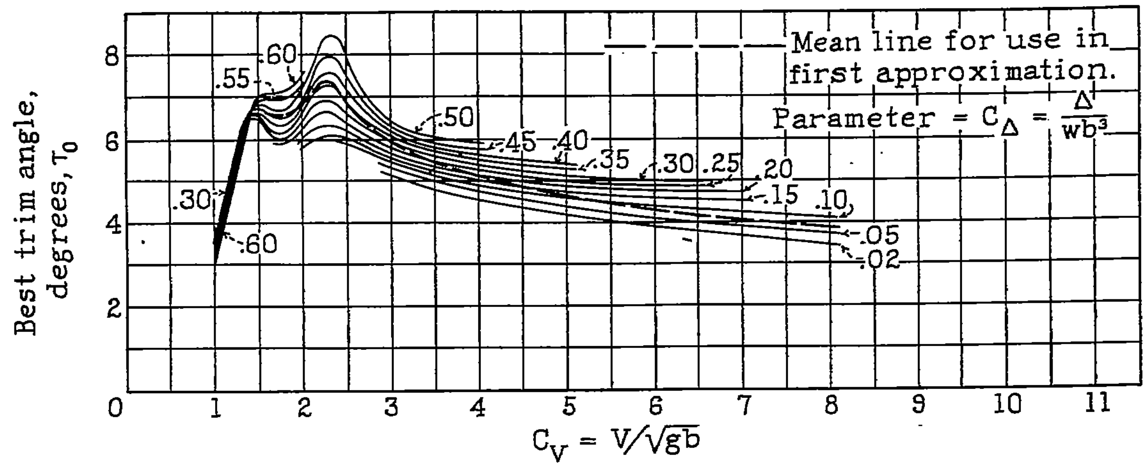

Figure 10.- Variation of best trim angle, τ_0, with C_V. Model 26.

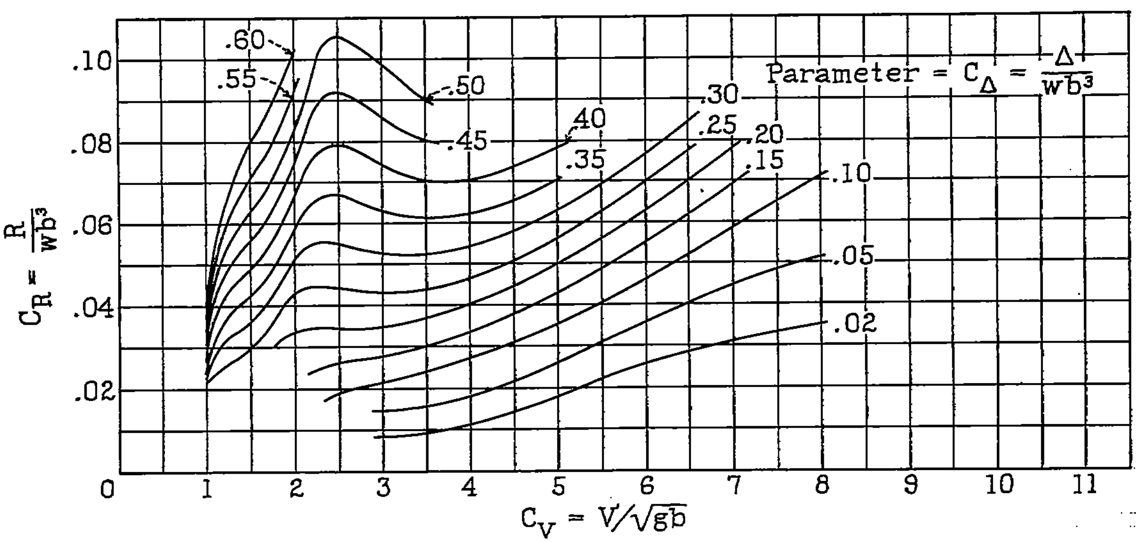

Figure 11.- Variation of C_R with C_V at best trim angles. Model 26.

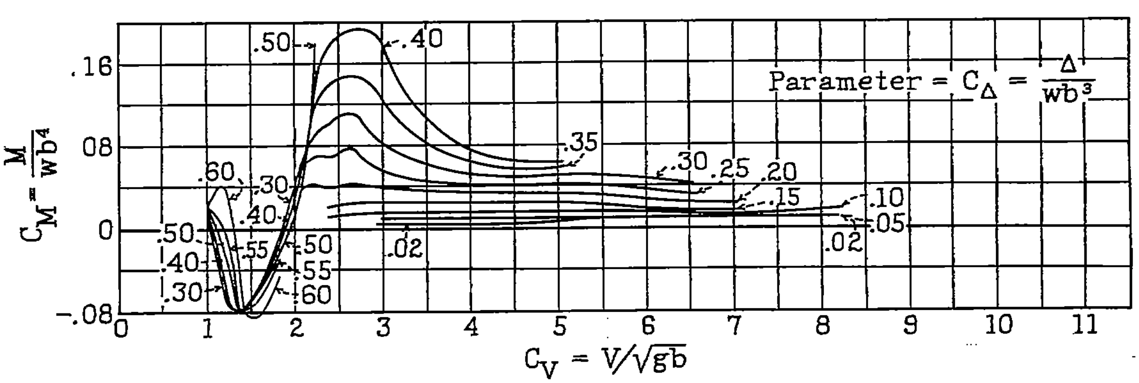

Figure 13.- Variation of C_M with C_V at best trim angles. Model 26

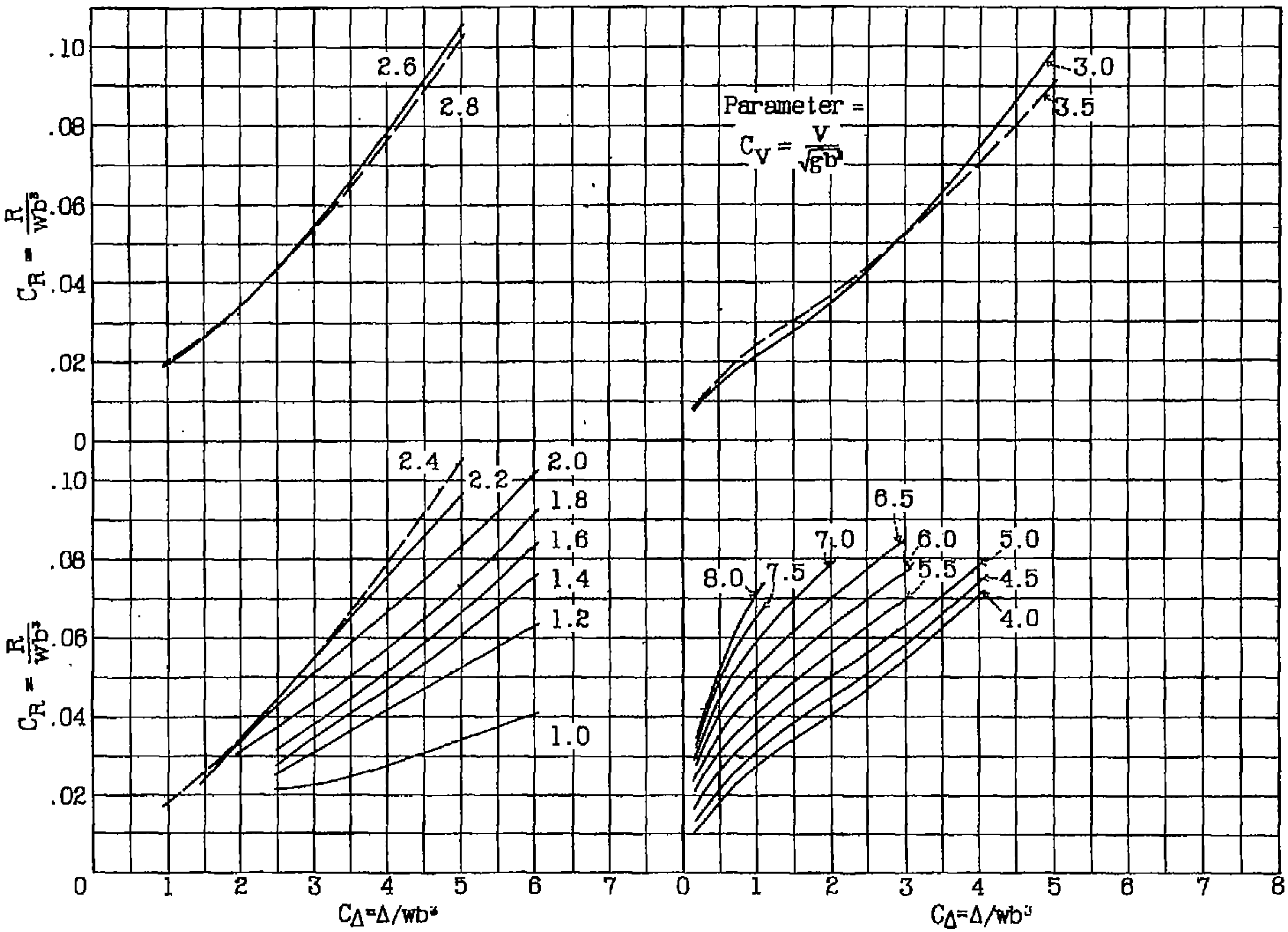

Figure 12.- Variation of C_R with C_Δ at best trim angles. Model 26

6.6 f.p.s. , $\tau = 3^\circ$, $\Delta = 120$ lb. 12.0 f.p.s. , $\tau = 7^\circ$, $\Delta = 60$ lb.

15.5 f.p.s. , $\tau = 7^\circ$, $\Delta = 100$ lb. 15.8 f.p.s. , $\tau = 9^\circ$, $\Delta = 100$ lb.

24.3 f.p.s. , $\tau = 5^\circ$, $\Delta = 80$ lb. 52.5 f.p.s. , $\tau = 3^\circ$, $\Delta = 20$ lb.

Figure 14. - Spray photographs of N.A.C.A. model 26

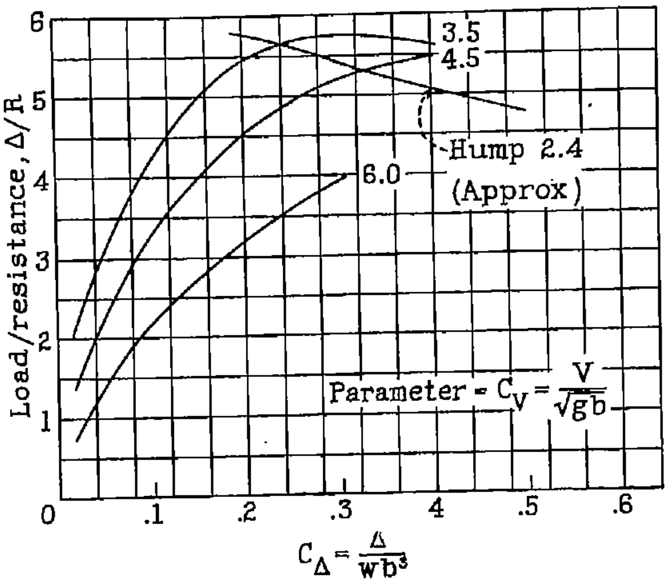

Figure 15.- Effect of C_Δ on Δ/R at best trim angles. Model 26.

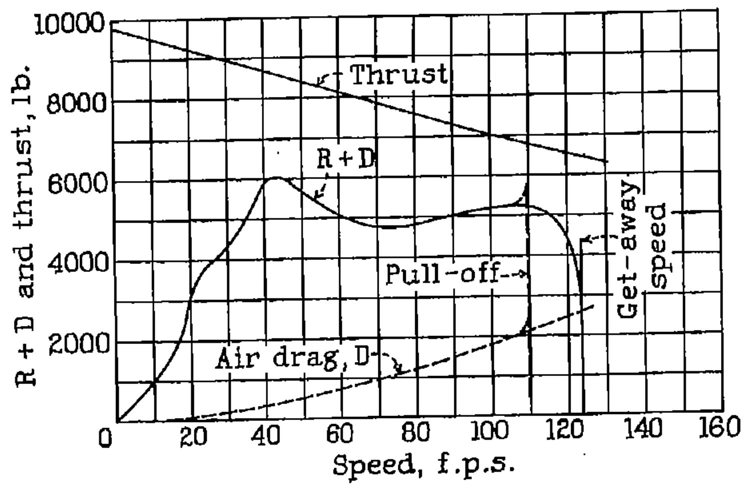

Figure 16.- Variation of R+D and thrust with speed. Sikorsky S-40.

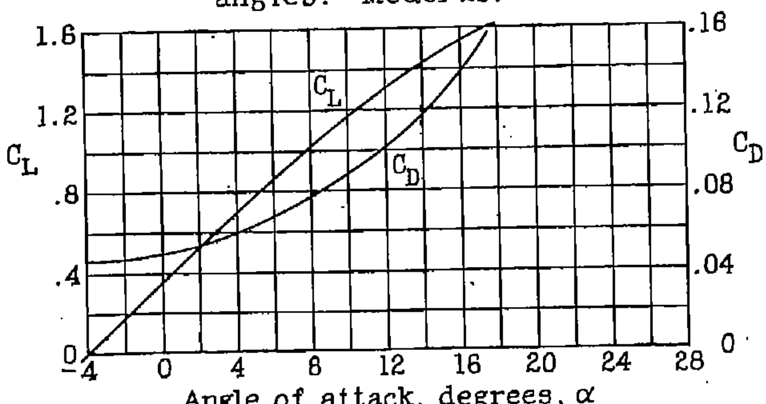

Figure 17.- Coefficients for Sikorsky S-40 flying boat. Hull excluded. Effective aspect ratio including ground effect = 12.2

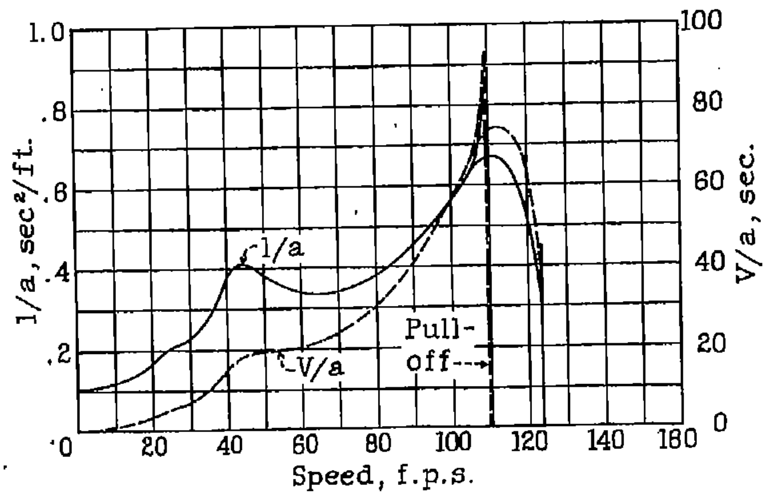

Figure 18.- Curves for determining take-off time and run. Sikorsky S-40.